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A Leftward Bias However You Look At It: Revisiting the Emotional Chimeric Face Task as a Tool for Measuring Emotion Lateralisation

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Abstract

Left hemiface biases observed within the Emotional Chimeric Face Task (ECFT) support emotional face perception models whereby all expressions are preferentially processed by the right hemisphere. However, previous research using this task has not considered that the visible midline between hemifaces might engage atypical facial emotion processing strategies in upright or inverted conditions, nor controlled for left visual field (thus right hemispheric) visuospatial attention biases. This study used novel emotional chimeric faces (blended at the midline) to examine laterality biases for all basic emotions. Left hemiface biases were demonstrated across all emotional expressions and were reduced, but not reversed, for inverted faces. The ECFT bias in upright faces was significantly increased in participants with a large attention bias. These results support the theory that left hemiface biases reflect a genuine bias in emotional face processing, and this bias can interact with attention processes similarly localized in the right hemisphere.

Introduction

M. P. Bryden was one of the very first laterality researchers to investigate hemispheric asymmetries in facial expression processing experimentally. In an early visual half-field study (Ley & Bryden, 1979), he used cartoon line drawings of different emotional expressions, ranging from extremely positive to extremely negative, and presented them tachistoscopically (85 ms) in either the left or right visual field. Bryden and his colleague found a significant left visual-field advantage for emotional facial expression recognition, supporting the prevalent view at that time of a right hemispheric superiority for face recognition and for processing emotional stimuli. The view that all emotions are preferentially processed by the right hemisphere independent of valence - the Right Hemisphere Hypothesis (e.g. Borod et al., 1998) - is still supported by more recent visual half-field studies (for reviews, see Mandal & Ambady, 2004; Najt, Bayer, & Hausmann, 2013). However, some research has led to alternative, and currently debated models (Abbott, Cumming, Fidler, & Lindell, 2013; Killgore & Yurgelun-Todd, 2007), describing the laterality of emotional processing: the Valence-Specific Hypothesis, that positive expressions (i.e. happiness, and by some accounts surprise) are preferentially left hemisphere processed, with negative emotions showing a right hemisphere bias (Adolphs, Jansari, & Tranel, 2001; Ahern & Schwartz, 1985; Jansari, Rodway, & Goncalves, 2011), and the associated approach-withdrawal related model in which approach emotions (anger, happiness, surprise) are left hemisphere dominant and withdrawal-related emotion (disgust, fear, and sadness) are right hemisphere dominant. The key variation between the latter two is the lateralization of anger (Harmon-Jones, 2004).

One particular behavioural paradigm which has been utilized in attempts to distinguish between these models is the Emotional Chimeric Face Task (ECFT). This task originated from Wolff (1933) and later researchers, such as Sackheim (e.g. Sackheim & Gur, 1978), as well as Levy, Heller, Banich and Burton (1983), who examined asymmetries in emotional facial expression by vertically dividing images of faces and creating mirrored composites from each half of the face, as a task to evaluate hemispheric asymmetries in emotional *perception.* The task has been used extensively in the years since (Bourne, 2008; 2010, 2011; Chiang, Ballantyne, & Trauner, 2000; Christman & Hackworth, 1993; Coolican, Eskes, McMullen, & Lecky, 2008; Coronel & Federmeier, 2014; Luh, 1998; Luh, Rueckert, & Levy, 1991; Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994; Rahman & Anchassi, 2012; Rueckert, 2005; Workman, Peters, & Taylor, 2000). In a typical version of the task, neurologically healthy participants are presented with two faces, one placed above the other. Each of these faces has been constructed so that one half-face (the left or right hemiface) displays an emotion (such as happiness) while the other hemiface is neutral in expression. Though the stimuli on a given trial are essentially identical and are merely mirror images, participants tend to report that the face presenting the emotional expression on the left hemiface (which relates to left from the viewer's perspective henceforth) appears more emotional. Due to the visual projection in humans, stimuli presented in the left visual field undergo primary visual processing by the right hemisphere. Under free-viewing conditions, when eye-movements are not controlled, these stimuli will undergo primary processing in both hemispheres due to eye movements. This finding is thus generally interpreted as support for the Right Hemisphere Hypothesis, which was Bryden's original observation, particularly because the strong left hemiface bias reported for happy chimeric faces, and also recently for surprised faces (Bourne, 2010; 2011; but see Rahman & Anchassi, 2012), is not predicted by other models.

However, alternative neuropsychological techniques do not provide such reliable evidence for the Right Hemisphere Hypothesis. For example, the visual half-field paradigm has often produced conflicting results, sometimes favouring right hemisphere models (e.g. Alves, Aznar-Casanova, & Fukusima, 2009; Ley & Bryden, 1979) and other times valence-specific asymmetries (e.g. Reuter-Lorenz & Davidson, 1981; Reuter-Lorenz, Givis, & Moscovitch, 1983). Indeed, in their recent review Najt et al. (2013) concluded that only a subset of negative emotions (anger, fear, and sadness) display any consistent laterality pattern, all in favour of the right hemisphere. Such a conflict may result from the different nature of the tasks: in comparison to the free-viewing conditions of the ECFT, stimuli in visual half-field tasks are presented extrafoveally in either the left or right visual field for very brief periods of around 150 ms (Bourne, 2006). Additionally, the two tasks rely on different measures with the visual half-field methodology focusing on performance measures (e.g. accuracy or response times) for emotion categorization, but the ECFT almost exclusively measuring perceptual preference (but also see Bourne, 2008, for analysis of reaction times in the ECFT). Nonetheless, this introduces the crucial issue that there may be some element of the ECFT itself that promotes a hemiface bias, rather than the emotions themselves eliciting asymmetric engagement of the hemispheres. In his own papers, Bryden was hesitant to accept the conclusion that task results reflected genuine asymmetry in a specific function until alternative explanations had been eliminated (Bryden & Mondor, 1991). Thus, the present study aims to consider some factors which may contribute to hemiface biases outside of emotion processing.

The orientation of the face within the ECFT is of particular interest given recent work (Bourne, 2011; Coolican et al., 2008; Luh, 1998). In broader terms, inverted faces are considered valuable control stimuli as their visual properties (including features and configural relationships) are identical to the upright equivalents (Valentine, 1988). Evidence from functional magnetic resonance imaging (fMRI) also suggests inverted faces are processed by the same brain regions (i.e., fusiform gyrus), albeit eliciting slightly less activation (Kanwisher, Tong, & Nakayama, 1998), while electrophysiological (i.e., ERP) data relating to emotional face presentation further indicates neural activity is similar regardless of orientation, although delayed with inversion (Eimer & Holmes, 2002). Critically for present purposes, inversion impairs individuals' ability to discriminate emotions efficiently (though still above chance; Bimler, Skwarek, & Paramei, 2013), supporting the idea that emotional face perception relies on configural processes which proceed best when the faces are presented upright. These configural processing mechanisms are thought to be right-lateralized (Abbott, Wijeratne, Hughes, Perre, & Lindell, 2014; Bourne, Vladeanu, & Hole, 2009). However, emotions with distinct featural changes (in particular the open mouth in happiness) might be processed based on their features (Calvo, Fernández-Martín, & Nummenmaa, 2012) in addition to configural processing, and as such emotions like happiness might be relatively unaffected by inversion. There is some evidence that featural processing of faces is left-lateralized (Bourne, Vladeanu, & Hole, 2009). Inverted ECFT trials thus control for the low-level visual properties related to the presentation of face stimuli, while also ruling out the possibility that any differences in biases between expressions can be accounted for by the fact that these simply have different visual properties, such as the distinct featural change in the mouth that indicates happiness.

It would be expected, then, that in the inverted ECFT there should be a reduced left hemiface bias, as inversion impairs typical emotional face processing mechanisms, or no hemiface bias, if participants are unable to perform the task and thus respond at chance. One important ECFT study by Bourne (2011), however, which is also one of the few studies to have considered all six basic emotions, found significant left hemiface (right hemisphere) biases across all emotions for upright faces, but for inverted conditions an overall *right* hemiface bias emerged, corresponding to the left hemisphere. Individual right hemiface biases were also reported for inverted facial expressions of happiness and surprise (i.e., positive valence emotions; Bourne, 2010) partially supporting the Valence-Specific Model. However, the results are interpreted by Bourne (2011) as corresponding to left hemisphere featural processing and right hemisphere configural processing mechanisms. It would appear then that when the general right hemisphere bias for configural facial processing is attenuated by inversion, left hemisphere featural processing drives the identification of positive expressions. This featural/configural distinction might partially account for differential support for the Right Hemisphere and Valence-Specific accounts across methods.

However, the results of Bourne's (2011) study draw attention to a potential issue that exists across much of the ECFT literature, which is the presence of a visible midline. This clear divide between the two contributing hemifaces may encourage the use of non-typical face processing styles, a criticism raised by Burt and Perrett (1997) with regard to the wider CFT literature. Considering again Bourne's (2011) study, it may be that the presence of a visible midline did not significantly alter or overcome the right hemisphere configural processing style typically adopted for upright emotional faces. However, inverting the face may have both impaired the use configural information and also, given the presence of an unnatural midline, encouraged an atypical (perhaps left-hemisphere/featural) face-processing strategy that would not otherwise have been engaged in the processing of inverted 'whole' faces. To remove this potential confound of a visible midline, studies have used midline-blended emotional chimeric face stimuli (Burt & Perrett, 1997).

Though midline-blending may represent a necessary step for the ECFT, there is also a more general concern regarding how specific the leftward bias observed in the task is, and whether it reflects a genuine functional hemispheric asymmetry of emotional face processing. In their critical review, Bryden and Mondor (1991) listed a number of factors which might explain reliable laterality effects observed in the literature, including eye-movement patterns and asymmetries of visual attention; on the latter, Bryden later observed by visually pre-cueing participants that asymmetries in lexical decision and identification of single letters could be explained by attentional effects (Mondor & Bryden, 1992). Indeed, some of these factors discussed by Bryden, such as the role of eye-movements, have already been observed in relation to the ECFT (e.g. Butler & Harvey, 2006). Crucially, however, one challenge to the interpretation that the ECFT strongly supports the Right Hemisphere Hypothesis is that the leftward bias is not a phenomenon restricted to emotional chimeric faces but also applies to visuospatial attention. This is demonstrated in numerous tasks, such as line bisection in neurotypical individuals, and has been termed 'pseudoneglect' (Bowers & Heilman, 1980; Hausmann, 2005; Hausmann, Corballis, & Fabri, 2003, Hausmann, Ergun, Yazgan, & Güntürkün, 2002; see Jewell & McCourt, 2000, for a review). In much the same way that a left hemiface bias in the ECFT is thought to indicate right hemispheric emotional face processing, the leftward biases shown towards stimuli in pseudoneglect tasks suggest a right hemispheric dominance in the allocation of attention, and as such stimuli in the left visual space are favoured over those in the right visual space (e.g., Hausmann, Corballis, & Fabri, 2003). Thus, this bias in spatial attention and the left hemiface bias typically found in ECFT might be confounded.

In some instances the left hemiface bias has been explicitly described as an attentional effect (Luh, 1998), as individuals who showed a greater bias to using information on the left of faces also showed a leftward bias in another task that did not concern emotional face processing (Luh, Rueckert, & Levy, 1991). Consistent with the idea of the left of faces and the left of stimuli bias having a common origin, patients with attentional deficits in the left visual field demonstrated *right* biases in the ECFT and in various pseudoneglect tasks (Mattingley et al., 1994). However, Mattingley et al. found no evidence of correlation between ECFT biases and scores on their measure of pseudoneglect (the Greyscales task; Mattingley et al., 1994; Nicholls, Bradshaw, & Mattingley, 1999; Nicholls & Roberts, 2002) within controls or patients. Given the lack of firm evidence regarding the influence of attentional asymmetries, it is curious that ECFT studies do not typically investigate or control for this factor by utilizing a comparable measure of attentional bias, such as the Greyscales task (Mattingley et al., 1994; Nicholls, Bradshaw, & Mattingley, 1999; Nicholls & Roberts, 2002).

This study therefore aimed to extend Bourne's (2011) study by examining the extent to which all six basic emotions (i.e., anger, disgust, fear, happiness, sadness and surprise; Ekman, Friesen, & Ellsworth, 1972), within upright and inverted versions of the ECFT, are cofounded by the right-hemispheric bias in spatial attention as measured by the Greyscales task (Mattingley et al., 1994; Nicholls, Bradshaw, & Mattingley, 1999; Nicholls & Roberts, 2002). Given the sex difference in the ECFT bias (Bourne, 2005) and spatial attention (Hausmann, 2005), whereby males show stronger biases compared to females, participants' sex was also included as a factor in the analyses. It was hypothesized that a leftward (right hemisphere) bias would emerge for both the ECFT and the Greyscales task, and that biases in the Greyscales task would account, to some extent, for the biases in the ECFT if the latter is related to an attentional effect. Further, leftward biases in spatial attention should positively correlate with left hemiface biases. It was also hypothesized, based on previous studies of inversion in the ECFT, that left biases should be attenuated in inverted conditions (Coolican et al., 2008; Luh, 1998). Given that the presence of a visible midline is suggested to underlie the previous observation of right hemiface biases in inverted conditions (Bourne, 2011), the emergence of right hemiface biases in inverted conditions was not anticipated in the present experiment.

Method

Participants

59 participants (27 male, 32 female) from Durham University initially took part in the present experiment. Individuals were recruited by opportunity sampling or by use of the department's 'Participant Pool' (in the latter case, participation credit was awarded). Age ranged from 18-35 (M = 22.27, SD = 3.60). All participants reported being right-handed, which was confirmed with the Edinburgh Handedness Inventory (EHI) questionnaire (Oldfield, 1971). Laterality Quotients (LQs) were calculated for each participant from the Edinburgh Handedness Inventory as a value from -100 to 100 (positive scores indicating right-handedness and negative scores indicating left-handedness). The mean handedness LQ for males was 79.66 (SD = 17.52), ranging from 37 - 100, whereas the mean LQ for females was 80.24 (SD = 22.87), ranging from 23-100. There were no significant differences between male and female participants in terms of age, $t(57) = 1.14$, *n.s.* and handedness, $t(57) = 0.108$, *n.s*. Visual acuity was either normal or corrected-to-normal in all cases.

Apparatus

All tasks were carried out on a desktop computer with a resolution of 1024 × 768 and a refresh rate of 60 Hz. Participants were required to use a central chin rest at a distance of 57 cm from the computer screen.

Face Stimuli

Emotional face stimuli were novel chimeric faces derived from averages of the individuals featured in the Ekman and Friesen (1976) series of emotional facial expressions. Images of the same eight individuals were used to construct a symmetrical average face image (Tiddeman, Burt, & Perrett, 2001; Perrett et al., 1999) for the expressions of anger, disgust, fear, happiness, sadness, surprise, and neutral. Four male and four female faces were included within these averages to control for potential effects related to the gender of the stimulus face (e.g. Parente & Tomassi, 2008); it was thus not necessary or possible to analyse the results according to the gender of the face stimuli. With the exception that symmetrical averages of individual facial expressions were used, the method of construction followed that of Burt and Perrett (1997) where full details can be found. In brief, to produce a chimeric face image the shape (position of features) and pixel luminance information of one expressive average image and the neutral average image were merged with 100% of the shape and luminance information being taken from the neutral image on one side and the expressive image on the other with information being taken from both face images in a broad graduated band across the vertical midline. This band was roughly as wide as most individuals' noses. The resulting chimeric face was then masked to remove features outside of the face and can be seen in Figure 1.

Thirteen face stimuli in total were used: six emotional chimeric face types in both emotional-neutral hemiface arrangements as well as one full-faced neutral stimulus which had been prepared in the same way as above, but using the neutral average face to for both sides rather than one neutral and one expressive average face. Neutral-neutral face trials were not analysed. Inverted stimuli were simply the upright stimuli inverted over a horizontal axis.

Emotional Chimeric Face Task

Stimuli were presented in pairs one above the other at a distance of 1 degree of visual angle above and 1 degree of visual angle below fixation. Each stimulus measured 6.5 degrees visual angle in height and 4.5 degrees visual angle in width. Each of the chimeric expressions was presented 16 times, with seven levels of expression (anger, disgust, fear, happiness, neutral, sadness, surprise), two levels of expressive face side position (expressive faces on top left and bottom right, expressive faces on top right and bottom left), two levels of orientation (inverted, upright) and four repetitions. A total of 112 experimental trials were thus presented in two separate blocks (one upright the other all inverted). Block order and trial order within a block was randomized with the proviso that no more than three ‘similar’ trials (trials with either the same emotion or the same visual field arrangement) were presented sequentially. A paper example trial was also presented during instruction which was not considered for analysis.

Figure 1. Examples of upright trails for each of the facial expressions (from left to right: anger, disgust, fear, happiness, sadness, surprise, and neutral). Within each trial-type, top and bottom presentation was balanced. Inverted trials utilized horizontally-mirrored versions of the same stimuli. These chimeric face stimuli are available on request from one of the authors (DMB).

In each trial, a fixation cross was presented for 2000 ms followed by the presentation of the face pair for a maximum exposure time of 4000 ms. All participants indicated within this 4000 ms which face appeared ‘more emotional’ via key press of ‘1’ for the upper stimulus and ‘2’ for the lower stimulus. This 4000 ms maximum interval was chosen to allow participants time to make a decision. Once the response was registered, the next trial was initiated immediately. If no response was registered within 4000 ms, the next trial would begin and the ‘missed’ trial was presented again at the end of the block. However, trials missed again were counted as ‘no response’.

LQs were calculated by subtracting the number of trials in which the participant displayed a right bias from the number of trials in which the participant displayed a left bias and then dividing by the overall number of trials. This resulted in LQ values between -1 (maximum right hemiface bias) and 1 (maximum left hemiface bias). In the rare case that trials were registered as 'no response', LQs were calculated with the number or left and right bias trials which were responded to within the time limit given.

Greyscales Task

The computerized Greyscales task (as developed by Nicholls et al., 1999; available to download at http://www.flinders.edu.au/sabs/psychology/research/labs/brain-and-cognition-laboratory/the-greyscales-task.cfm) was utilized. Six of the pre-programmed bar lengths (320 × 79, 400 × 79, 480 × 79, 640 × 79, and 720 × 79 pixels) were presented, each 16 times to give a total of 96 trials overall. For each bar length, half of the trials were arranged so that the upper stimulus displayed darkness in the left visual field (and the lower stimulus displayed darkness in the right visual field), and the remaining half were arranged thus that the lower stimulus displayed darkness in the left visual field (with darkness in the right visual field for the upper stimulus). The overall luminance of both bars present within each trial did not differ. Participants would indicate by key press ('T' for the upper bar, 'B' for the lower bar) which bar they believed appeared darker overall. Each trial was presented for a maximum of 2000 ms, with no time limit of response. The interval between response and the onset of the next trial was 1500 ms. The timings used and reported here are the default settings for the Greyscales Task program. LQs were calculated as described for the ECFT, such to produce values between -1 (maximum right bias) and 1 (maximum left bias).

Procedure

Written consent was received by all participants before the completion of the EHI (Oldfield, 1971). Participants were then seated before the computer. Prior to the beginning of each task (which were given in a randomized order) instructions were read aloud and examples were presented. Once it was assured that the participant had understood instructions and was ready to begin the task, the participant placed their chin on the rest, and the experimenter then switched off the overhead lighting (such that a desktop lamp provided dim central lighting from behind the monitor). The relevant trials were then initiated. For both tasks, the response key for the upper stimulus was pressed with the left index, and the bottom stimulus key was pressed with the right index finger. Once all tasks had been completed, the experimenter presented the participant with a printed debrief and awarded any Participant Pool credit as necessary.

Results

A Greenhouse-Geisser correction was applied whenever sphericity was significantly violated. Post-hoc tests were Bonferroni-corrected.

Emotional Chimeric Face Task

LQs for the ECFT were submitted to a 2 × 2 × 6 mixed model ANOVA, with Orientation (upright, inverted) and Emotion (anger, disgust, fear, happiness, sadness, surprise) as within-subjects factors, and Sex as a between-subjects factor. The ANOVA revealed a significant intercept, $F(1, 57) = 32.11$, $p < .001$, $\eta_p^2 = .36$, indicating that participants showed an overall leftward bias (M ± SE, 0.17 ± 0.03) which differed significantly from zero (no bias). There was also a significant effect of Orientation, $F(1, 57) = 13.31$, $p = .001$, $\eta_p^2 = .19$, with a greater bias towards the left hemiface in upright faces (0.27 ± 0.04) than inverted faces (0.07 ± 0.04). Post hoc one-sample *t*-tests were then conducted separately for both upright and inverted orientations to investigate whether LQs differed significantly from zero (no left/right hemiface bias). LQs for upright faces demonstrated a left hemiface bias significantly different from zero, $t(58) = 5.94$, $p < .001$. LQs for inverted faces were also positive, indicating a left hemiface bias, which was almost significantly different from zero, $t(58) = 1.91$, $p = .061$. There was also a significant effect of emotion, $F(4.28, 243.86) = 2.45$, $p = .043$, $\eta_p^2 = .04$. Pairwise comparisons (Bonferroni-corrected) revealed that happiness (.09 ± .04) showed a significantly smaller bias than surprise (.22 ± .04), with all other comparisons $p > .05$. There was also an additional between-subjects effect of participant sex, $F(1, 57) = 4.45$, $p = .039$, $\eta_p^2 = .07$. Males showed a significantly higher mean bias towards the left (.23 ± .04) than females (.11 ± .04).

Given that the analysis of the LQs for the Greyscales Task revealed a significant intercept, $F(1, 58) = 39.89$, $p < .001$, $\eta_p^2 = .41$, which indicated that participants more often perceived bars which were darker in the left visual field to be darker overall than bars which were darker in the right visual field (0.26 ± 0.04), the ECFT data was reanalysed with Greyscales LQ included as a covariate in the analysis. However, the overall left bias in ECFT indicated by the intercept was still significant, $F(1, 56) = 12.11$, $p = .001$, $\eta_p^2 = .18$, albeit reduced in effect size. However, the between-subjects effect of the Greyscales LQ covariate data was not significant, $F(1, 56) = 2.19$, $p = .144$, $\eta_p^2 = .04$. In comparison to the previous analysis, the effect of emotion was no longer significant and revealed only a trend, $F(4.27, 239.07) = 1.92$, $p = .104$, $\eta_p^2 = .03$. Additional Pearson's correlations (one-tailed) between the Greyscale LQs and the overall upright ($r(57) = .19$, $p = .074$) and inverted ($r(57) = .07$, $p = .297$) ECFT LQs were both not significant. There were no other differences in the main effects/interactions to the previous analysis. All individual LQs are shown in Figure 2.

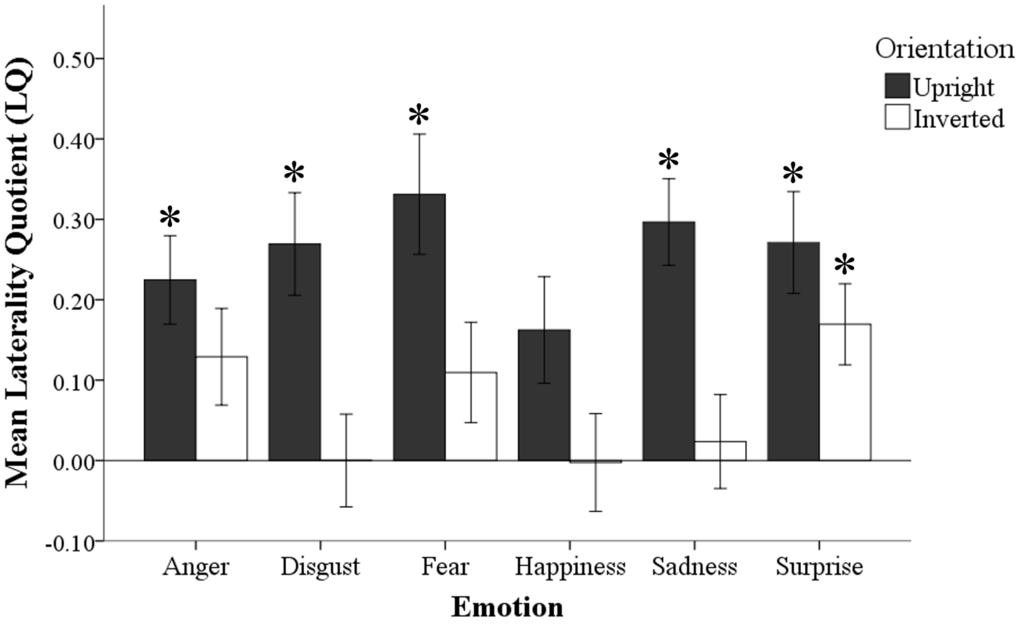

Figure 2. Individual mean LQs for each basic emotion (anger, disgust, fear, happiness, sadness, surprise) according to orientation (upright, inverted). Positive scores indicate a left hemiface bias. Error bars represent ± one standard error. Asterisk indicates a significant left hemiface bias, $p < .01$ (Bonferroni corrected).

To test the hypothesis that the EFCT bias was only affected in participants with a clear attention bias, the sample was divided in two groups based on a median split of the Greyscale LQ (cut-off score = 0.27), one with a small, non-significant (-0.1 ± .04), $t(27) = 0.33$, $p = .744$, and one group with a large (significant) attention-bias (0.50 ± 0.03), $t(30) = 16.67$, $p < .001$, When the median-split (Group factor) was added to the ANOVA as a between-subject factor, rather than including Greyscales LQ as a covariate, as in the previous analysis, the results revealed a marginally-significant interaction between Orientation and Group, $F(1, 55) = 3.92$, $p = .051$, $\eta_p^2 = .07$. Post hoc tests (Bonferroni) showed that the group with a large attention bias had a significantly larger ECFT bias for upright faces, (0.32 ± 0.06) than for inverted faces (0.05 ± 0.06), $t(30) = 3.21$, $p = .003$. In contrast, the group with a small, non-significant attention bias, showed smaller ECFT bias in both upright (0 .19 ± 0.07) and inverted faces (0.10 ± 0.05), which did not significantly differ, $t(27) = 1.69$, $p = .102$. Neither the main effect of Group, $F(1, 55) = .66$, $p = .42$, $\eta_p^2 = .01$, nor any other interaction with Group approached significance, all F < 1.03, *n.s.*

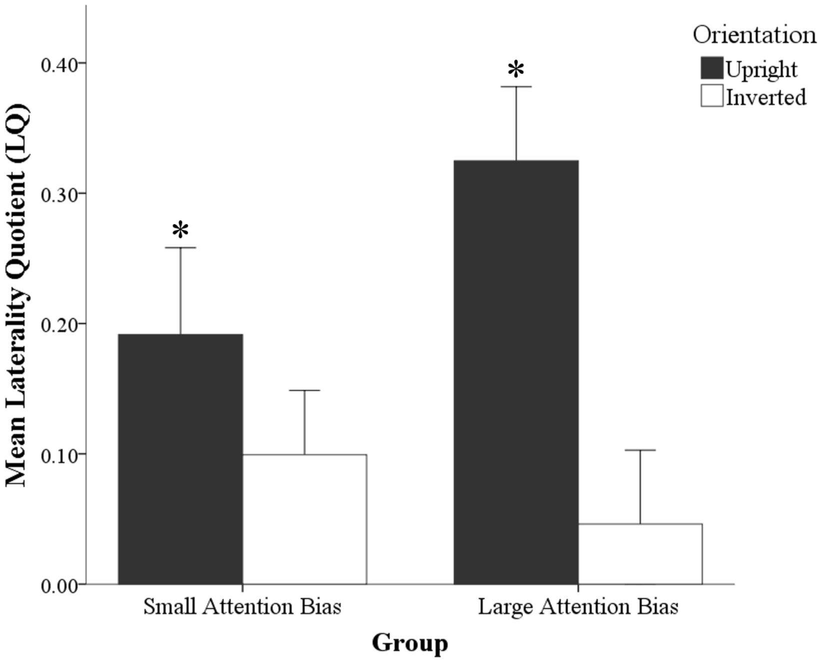

Figure 3. Mean LQs calculated from all trials for both the small and large attention bias groups, organised according to orientation (upright, inverted). Error bars represent one standard error. Asterisk indicates a significant left hemiface bias, $p < .01$ (Bonferroni corrected).

Discussion

M. P. Bryden is well-known for his role in the view that all facial emotions are processed by the right hemisphere (Ley & Bryden, 1979), and more generally for his research on the interaction between attention and hemispheric differences (Bryden & Mondor, 1991, Mondor & Bryden, 1992). This study, in line with these key ideas, investigated whether novel (midline-blended) emotional chimeric face stimuli produced left hemiface (related to right hemisphere) biases independent of leftward biases in visuospatial attention. Chimeric faces relating to the basic emotions produced leftward biases in both upright and inverted conditions, in accordance with models whereby processing of all emotional faces is lateralized to the right hemisphere (e.g. Borod et al., 1998) rather than differentially lateralized depending on valence (e.g. Adolphs, Jansari, & Tranel, 2001; Ahern & Schwartz, 1985; Jansari, Rodway, & Goncalves, 2011). The leftward ECFT biases were not significantly affected by a left visual field bias in visuospatial attention, as measured by the Greyscales task (Mattingley et al., 1994; Nicholls, et al., 1999; Nicholls & Roberts, 2002). In addition, the large independent effect observed for the ECFT, and lack of significant correlation between the ECFT and Greyscales task, is inconsistent with the hypothesis that a general attentional asymmetry accounts for left hemiface biases. Further, with the utilization of midline-blended stimuli, this study did not replicate Bourne's (2011) finding that inverted chimeric faces produce right hemiface biases, instead demonstrating a general leftward bias even when stimuli were inverted. This is consistent with the effect observed by Bourne (2011) having been caused by atypical processing associated with the midline of stimuli being visible.

Overall, our finding that facial expressions presented on the left of faces are seen as more intense than those on the right is consistent both with Bryden's pioneering research and with studies of non-blended chimeric faces, many of which have been limited to either smaller clusters of the basic emotions (e.g. Chiang et al., 2000; Christman & Hackworth, 1993; Coolican et al., 2008; Coronel & Federmeier, 2014; Levy et al., 1983; Rueckert, 2005) though some have investigated all six basic emotions (e.g. Bourne, 2010, 2011; Workman et al., 2000). The blended stimuli are thus equally effective as previous versions of the task at eliciting biases, whilst providing a number of additional advantages. To construct the faces, equal numbers of male and female individuals were used, which means these stimuli are androgynous. The gender of the face (as well as the observer, as demonstrated in the present analyses) have been found to influence asymmetries in chimeric face tasks. Parente and

Tomassi (2008), in a tachistoscopic presentation study, found that the leftward bias was reliant on the presentation of female (rather than male) left-hemifaces. Rahman and Anchassi (2012) alternatively noted that male participants are broadly less lateralized when presented with female, compared to male, emotional chimeric faces. It has also been reported that female observers are slightly weaker biases than males in the ECFT (Bourne, 2005), which is in line with our results. The results of the present study also suggest that, when inverted, the chimeric faces shown here should provide better control stimuli, as the reduced leftward biases are in line with the expected effect of inversion on typical configural processing mechanisms. The reversed (rightward) biases for non-midline-blended inverted faces observed by Bourne (2011), however, are not in line with this expectation. Both factors have significant implications for using the ECFT in situations requiring high levels of control, as in work with patients or within neuroimaging. Several studies have already demonstrated the utility of the ECFT for investigating patients with psychiatric disorders like depression (for an overview, see Kucharska-Pietura and David, 2003), as well as neurodegenerative disorders connected to emotional face perception deficits (e.g., Parkinson's Disease; Smith et al., 2010). Neural activation associated with the ECFT has also been examined in healthy individuals with fMRI (Killgore & Yurgelun-Todd, 2007). Given such applications of the ECFT, it is suggested that the present stimuli be used in such future investigations because of the advantages described.

Though the results of this experiment do not suggest any clear evidence of a difference in bias between emotions, it might be noted that in the upright emotional faces, happiness did not produce a significant individual bias (though the bias was significant without a corrected *p* value). This could thus be explained by our choice of a strict criterion *p* value for error inflation, or the relatively fewer (eight) number of trials presented in this experiment compared to other 'happiness only' ECFT studies (e.g., Bourne, 2008; Levy et al., 1983;

Rueckert, 2005). Given that full-faced happy expressions (in comparison to other basic emotions) are suggested to be processed bilaterally in the neuropsychology literature (Abbott et al., 2013; Adolphs et al., 2001), it may also be that midline-blended happiness stimuli do not produce a strong bias as both hemispheres are involved in the perception of happiness. As further alternative, this result may be related to the happiness being communicated mainly through a single feature, the mouth, which being a single feature may be processed differently than the eyes. In support of this interpretation, when a midline is present, which could cause the mouth to be processed in some ways as two features, a significant leftward bias for happy faces is found (Bourne, 2011). Further experiments might examine the laterality biases observed for blended and non-blended stimuli within the same sample to address these alternative accounts.

This study also compliments a growing body of evidence that suggests the results of ECFTs are not artefacts of alternative factors such as those Bryden suggested based on a critical review (Bryden & Mondor, 1991), i.e. eye-movement patterns (Butler & Harvey, 2006; Ferber & Murray, 2005), or scanning biases (Coronel & Federmeier, 2014). While attentional biases appeared to account for some variation in ECFT scores, the lack of effect of Greyscales LQs as covariate suggests that ECFT biases are largely independent from the attention bias. On the other hand, however, our data revealed that when the sample was divided into two groups with either small or large attention biases, as assessed with the Greyscales task (Mattingley et al., 1994; Nicholls, Bradshaw, & Mattingley, 1999; Nicholls & Roberts, 2002), the latter subsample showed a significant effect of orientation, with a strong ECFT biases for upright faces. Together with the covariance analysis, the findings suggest that the bias in emotional face processing depends significantly from the degree of participants' attention bias, at least for upright faces, although the relationship between both biases is probably not linear. Indeed, these results might suggest that while the hemiface biases and attentional biases observed are both genuine (i.e. hemiface biases do not simply reflect attentional asymmetries), sufficiently strong attentional leftward biases in attention will increase the leftward bias seen for faces. This finding is partly in line with previous work suggesting that attentional asymmetries and happiness ECFT biases correlated with some elements of distinct laterality (Luh et al., 1991), whereas it conflicts with findings suggesting that both biases were not significantly correlated with each other (Mattingley et al., 1994). The present study, which improved on previous investigations by investigating all basic emotions, supported the former. The discrepancies within the literature, as well as the reduced effect size for the ECFT when including the Greyscales data as a covariate, might, for instance, also be explained by the Greyscales data accounting for some individual differences in participants' performance within the asymmetry measures generally (such as alertness at the time of testing, or willingness to engage in the tasks). In other words, the increase in ECFT bias in participants with large Greyscales LQs indicates that attentional biases are a potential confound when utilizing the present stimuli in future studies of healthy right-handed participants.

The consistent left hemiface biases observed within the ECFT are slightly puzzling given mixed evidence for the lateralization of facial expression processing from methodologies like the visual half-field paradigm. As previously described, the visual half-field paradigm has offered differential support for both Right Hemisphere and Valence-Specific Models (Najt et al., 2013). As Najt and colleagues point out, however, visual half-field studies have not always addressed potential language confounds. As participants are sometimes required to ascribe verbal labels to face stimuli, this may cause an unintended activation of the left hemisphere via language processing. This is seemingly not an issue for the ECFT. In some studies (like the present study) participants can simply be asked which of two faces is more emotional, and though the majority of studies of chimeric faces *do* involve verbal labels, where for instance participants indicate which face was ‘happier’ (e.g., Bourne & Gray, 2011; Christman & Hackworth, 1993; Coronel & Federmeier, 2014; Levy et al., 1983), the significant right hemisphere biases observed suggest no influence in the task that could reasonably be linked to left hemisphere language factors. The lateralization of language may affect visual half-field studies because of the more rapid and reflexive nature of the response required.

The tachistoscopic (< 200 ms) presentation times used within visual half-field paradigms may also promote feature-based strategies (see Bimler et al., 2013). For instance, Calvo et al. (2012) suggested, based on a series of experiments with ‘blended’ expressions (whereby the mouth is smiling but the eyes present a different basic emotion), that featural information from the mouth is accessible earlier (< 170 ms after onset) than a configural representation in which the conflicting content is included. As feature-based processing has been suggested to be left lateralized (Bourne et al., 2009), it might account for right visual field biases regarding positive emotions (i.e. happiness, and perhaps surprise, both of which have large featural changes). Using equivalent presentation times within the ECFT, and also analysing reaction time biases (see Bourne, 2008), might therefore provide a way to compare the results of these methods and address this hypothesis. Tachistoscopic presentation should also theoretically affect proper integration of high spatial frequency information with low spatial frequency information, the former thought to be processed slightly earlier (Goffaux et al., 2011; Sergent, 1989). The ECFT (being a central free-viewing task) would normally allow proper integration, and thus be unaffected by this issue, whereas it may have more influence on reaction time biases in the visual half-field. Given known differences between emotions regarding the usefulness of high and low spatial frequency in classification (Smith & Schyns, 2009), as well as hemispheric asymmetries in spatial frequency processing (Kitterle & Selig, 1991; Sergent, 1982, 1987), this might also provide a promising area for further exploration with regard to the inconsistencies between laterality measures.

Overall, the present study is one of few ECFT studies to present all six basic emotions in both upright and inverted conditions, and, to the best of our knowledge, the only one to account for potential confounds introduced by both visible midlines and laterality biases in visuospatial attention. As a result, the finding that left hemiface biases are reduced but not 'reversed' in inverted conditions, nor abolished by accounting for attentional biases, provides much stronger evidence in favour of the Right Hemisphere Hypothesis of emotion processing. This is in line with M. P. Bryden's discovery (Ley & Bryden, 1979) more than three decades ago. The greater applicability of the novel stimuli presented here to emotion research, in comparison to previous ECFT stimuli, has thus been highlighted.

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